Chapter 3

Water Quality

Introduction

This chapter describes the types of water quality impacts potentially attributable to specific nutrients and pollutants in stored biosolids and other organic materials. In addition, key concepts in construction and management of storage systems that are known to work well in preventing water quality impacts from biosolids storage are discussed and related specifically to storage management practices recommended in Chapter 5 (Critical Control Point 3).

Water Quality Issues

Measurements of the following constituents of organic and inorganic materials stored on and/or applied to soil are customarily made to assess their potential impact on water quality. Table 3-1 summarizes these components relative to biosolids storage and their potential impacts on water quality:

- **Nutrients**
- **Organic matter**
- **Pathogens**
- **Metals**

Assessment of the presence of constituents such as nutrients, organic matter, pathogens or metals is the first step in developing effective water quality protection practices for stored materials. The second step is to examine the possible ways of transport. Constituents can only have an impact on water quality if significant amounts of the material reach surface or ground water. Good storage design and use of appropriate management practices effectively block potential transport pathways.

Movement of constituents is driven primarily by:

1. precipitation events

2. runoff and erosion of soluble and particulate components (including nutrients, organic matter, and pathogens to surface waters)

3. leaching to ground water of soluble nutrients and compounds.

In addition, wind erosion can contribute to loss of dry or composted material under arid, windy conditions that may also impact water quality.

Nutrients, Organic Matter, and Impacts on Surface Water

The content and form of nitrogen (N) and phosphorus (P), which must be taken into consideration, in specific biosolids, vary depending on wastewater sources and treatment processes. Like all organic residuals, biosolids contain significant amounts of N and P. Proper storage conserves these nutrients until crops can use them during the growing season. Good management of stored organic residuals is needed to prevent excess amounts of organic or inorganic N from entering surface or ground water.

Runoff of nutrients can contribute to eutrophication of surface water, which may impair its use for fisheries, recreation, industry and drinking water source. Nitrogen is the primary contributor to eutrophication in brackish and saline waters (e.g., estuaries), and to some extent in freshwater systems. However, P concentration is usually the controlling eutrophication factor in freshwater. Both nitrate and ammonia are water soluble, and thus, are transported in leachate and runoff. Organically bound N does not interact in the environment until it is mineralized into water soluble nitrate. Ammonia can be toxic to fish.

Excess nutrients and organic matter in surface water can increase the growth of undesirable algae and aquatic weeds. The carbon and nutrients in organic matter serve as food for bacteria, thus adding organic matter and nutrients to water can directly increase BOD, deplete dissolved oxygen levels in water, and accelerate eutrophication. The amount of oxygen needed to decompose the organic matter that is suspended in the water is called the Biochemical Oxygen Demand (BOD). Low oxygen levels resulting from high BOD stress fish, shellfish and other aquatic invertebrates. In a worst-case scenario, such as a direct spill of material from a storage facility into a waterway, heavy organic (BOD) and ammonia-N loadings could deplete oxygen levels rapidly and lead to septic conditions and fish kills.

The majority of P binds to mineral and organic particles and is therefore subject to runoff and erosion rather than leaching, except under conditions of very sandy soils with low P binding capacity. Eroded particulates also serve as a physical substrate to convey adsorbed P, metals and other potential pollutants in runoff.

Nutrients and Groundwater

The main concern with groundwater impacts of longer-term stockpiles (organic or inorganic) is the potential for leaching of soluble nitrate-N, which can impact local wells or eventually discharge to surface waters and contribute to eutrophication. Such situations have occurred in agricultural regions of the U.S. where excessive amounts of inorganic fertilizer or animal manures have been applied over several years. The high nitrate levels in wells have resulted in some cases of methemoglobinemia in susceptible infants. This rare condition reduces the blood's ability to carry oxygen efficiently, hence the condition's other name "blue baby syndrome." Elevated nitrate in water can have the same effect on immature horses and pigs and can cause abortions in cattle. Water management practices at storage sites must be adequate to protect against such impacts. Phosphorus is not a drinking water concern, because it is not a health concern for humans or animals as nitrate is, and it binds to iron and soil minerals and has low water solubility.

Pathogens

In the U.S., biosolids that are stored prior to land application must have been treated to meet USEPA Part 503 Class A or Class B pathogen density limits. The requirements for these types of biosolids can also include restricted access to field sites (Class B) to protect humans and animals from infection that might potentially result from direct contact with biosolids. Protection of water sources from contamination by residual pathogens or parasites in Class B biosolids can be accomplished through proper site selection, buffers and management practices as described in Chapter 5.

In general, soil is an effective barrier to the movement of pathogens via leachate into groundwater. Both organic matter and clay minerals in soil physically filter, adsorb, and immobilize microorganisms, including protozoan cysts, and parasitic worm ova. However, sandy soils are typically very porous and cannot adsorb or immobilize microbes as well as clay and loam soils containing organic matter, thus they are not as effective retardants to the movement of pathogens. Soils in general are subject to a range of physical, chemical, and biological conditions that destroy pathogens such as: extremes of wetness and dryness; temperature variations; and attack by natural soil microbes.

Metals and Synthetic Organic Chemicals

Like other residuals, biosolids may also contain measurable levels of metals and synthetic organic chemicals. In terms of organic and inorganic residuals, the same management practices that effectively isolate nutrients from surface and groundwater resources during storage are equally effective in containing any metals or synthetic organic chemicals. The potential for water quality impacts from metals or synthetic organic chemicals present in biosolids are minimal from the outset because of their inherently low levels. Biosolids suitable for land application must meet stringent quality standards for metal concentrations under Part 503 regulations.

With the widespread implementation of industrial pretreatment programs, biosolids used in land application increasingly comply with the most conservative of Part 503 metal standards. In addition, metals in biosolids are bound strongly with other biosolids constituents and, are not highly water soluble, hence they cannot leach into ground water. According to a recent review by the National Research Council (NRC), toxic organic compounds typically are not found in biosolids in significant levels. This is primarily attributable to effective industrial pretreatment programs and to the destruction or volatilization of organics during the treatment process. The NRC report also noted that "PCBs and detergents are the only classes of synthetic organic compounds that occur in biosolids at concentrations above levels found in conventional irrigation water or soil additives". PCBs bind to particulates and are relatively water insoluble and so are not susceptible to leaching. In addition, the low PCB levels in biosolids continue to decline due to enactment of a ban on production and use of PCBs in the United States. Detergent compounds including surfactants and binders have been found in biosolids in relatively high concentrations (0.5 - 4.0 g/kg dry weight), however they bind to biosolids organic matter, rapidly biodegrade, and do not readily leach.

Table 3-1. Potential Ground and Surface Water Quality Impacts Resulting from Improper Management of Water at Storage Sites

Biosolids Constituent	Potential Water Quality Impacts	Behavior, Transport Mechanism, and Mitigating Factors
Nitrogen	Eutrophication Human/Livestock/ Poultry health effects	Nitrate-N, Nitrite-N, and Ammonium-N are water soluble and can move in runoff or leachate
Phosphorus	Eutrophication	Predominately particulate-bound transported by erosive surface runoff
Organic Matter	Depletes oxygen levels in water	Soluble and particulate-bound movement of organic matter in surface runoff.
Particulates	Siltation or turbidity. Carrier for other pollutants	Mass transport in surface runoff.
Pathogens	Transmission of viable disease-causing bacteria, viruses or parasites	Insignificant levels in Class A biosolids, potentially present in Class B materials. Physical transport in sediment, runoff, and leachate from Class B biosolids is possible.
Regulated Metals	Toxic effects	Not very water soluble; reduced through pretreatment programs and Part 503 limits.
Toxic Organic Chemicals	Toxic effects	Reduced through industrial pretreatment programs and WWTP processes.

Management Approaches

This section summarizes the key storage design and management elements that address the water quality issues identified in Table 3-1. Water quality protection practices are based on three key concepts:

Protecting Water Quality during Storage of Biosolids:

- Keep clean runoff clean by minimizing contact with stored biosolids.
- Properly manage water that comes into contact with stored biosolids.
- Prevent movement of the biosolids into water resources

Keep Clean Water Clean

Minimizing the amount of water that comes into contact with stored biosolids is the first step in keeping nutrients and pollutants out of water resources. Practices used under various storage scenarios to achieve this include:

- Proper site selection to avoid run-on, flooding, or high water tables that intercept stored biosolids (see Chapter 5 also).
- Installation of upslope diversions to channel runoff away from a field stockpile or constructed storage facility (see Appendix C also).
- Containment of biosolids in enclosed structures or tanks.

Manage Water that Contacts Biosolids

Any significant precipitation or up-slope runoff that comes in contact with stored biosolids may contribute nutrients, pathogens or pollutants. Whether this water accumulates on or near the biosolids, runs off or leaches through the soil, it has the potential to transport contaminants to water resources. Practices to address this issue include (see also Chapter 5 for details and Appendix C):

- Proper shaping of field stockpiles to shed water and avoid puddles of water, or infiltration of water through a stockpile and subsequent loss through runoff or leaching.
- Construction of enclosed storage facilities or tanks.
- Construct lagoons/pads with impervious earthen, concrete or geotextile liners.

- Removal of accumulated water to sites where liquid may be applied.
- Providing buffers between storage areas and waterways.

Preventing Leaching

For permanent, long term storage facilities, an impermeable liner (i.e., earthen, geotextile or concrete) is recommended to ensure against leaching. For all constructed storage facilities, site soils and water table investigations are essential to ensure stable foundations. Soil settling and shifting can result in leakage through cracks. High water tables may float concrete pads or rupture the watertight seals of lagoons.

For short-term field storage, liners are generally unnecessary. Proper shaping of stockpiles encourages shedding of precipitation to prevent infiltration of water and subsequent leaching. Stockpiles should not be located on soils in environmentally sensitive areas with extremely high hydraulic conductivities with excessive infiltration rates, areas with very shallow seasonal high water tables or depths to bedrock, or areas adjacent to or on limestone features such as sinkholes or rock outcrops.

Managing Accumulated Precipitation (See also Chapter 5)

Accumulated water (i.e., precipitation) forms a separate layer on top of liquid or semisolid biosolids or collects in puddles after contact with the material. Overflow or runoff of this water to surface or ground water resources can be prevented or minimized by the following:

- For open storage facilities:
  - use sumps or gravity flow to direct accumulated water to on-site filter strips or treatment ponds,
  - mix accumulated water with biosolids for removal to land application site,
  - decant and transport water accumulations off-site to treatment facilities, or
  - apply to the land through irrigation systems (taking care not to exceed hydraulic loading rates to prevent ponding or runoff).

- For constructed facilities
  - roof to keep precipitation off the material
  - pads should have adequate slope to prevent ponding and appropriate flow management.

Prevent Movement of Biosolids

Direct deposition of biosolids in waterways has the greatest potential for significantly impacting water quality through additions of nutrients, organic matter, pathogens or pollutants. Management practices to prevent this occurrence include:

- Adequate buffers between storage area and water resources.
- Proper storage methods for the physical consistency of the biosolids.
- Proper design and maintenance of constructed storage facilities.
- A spill response and control plan supported by staff training and the availability of the necessary supplies and equipment.

Design and Management Approaches for Water Quality Protection

Proper materials management is an essential measure in water quality protection for all biosolids storage facilities and field stockpiling sites. Well-designed storage operations optimize water quality protection measures by including:

1. structural elements to minimize the potential for accidental spills,
2. operational procedures to reduce potential accidents, and
3. contingency plans to promptly mitigate spills if they do occur (see Chapter 5 for details).

Preventative Measures for Field Stockpiles

- Proper site selection including buffer distances and slopes.
- Proper vehicle and equipment safety features (e.g., waterproof seals on trailer tailgates), maintenance and operator training.
- Adequate staff training and proper operation of site to prevent accidental spills or losses of material to water resources (e.g., truck roll-overs, excess residuals left in loading areas).
- Written spill clean-up and contingency plans and advanced preparation (e.g., equipping storage sites and vehicles with appropriate clean-up tools, and staff drills to ensure rapid and effective response to spills.

Figure 3-1. Staging of biosolids for immediate incorporation into the soil (Maryland.)

Preventative Measures for Constructed Facilities

- Soil strength and suitability assessments prior to construction to avoid uneven settling and other problems that lead to cracks or leaks.
- Adequate design volumes, including space for precipitation accumulations.
- Use of good engineering construction practices to prevent structural failures and malfunctions (e.g., impermeable liners or backflow regulators on gravity systems, paving and curbing of off-loading pads for permanent facilities).
- Proper vehicle and equipment safety features (e.g., waterproof seals on trailer tailgates), maintenance and operator training.
- Adequate staff training and proper operation of site to prevent accidental spills or losses of material to water resources (e.g., truck roll-overs, overtopping of freeboard).
- Written spill clean-up and contingency plans and advanced preparation (e.g., equip sites and vehicles with clean-up tools; conduct staff drills to prepare for effective spill response).

Managers of stored biosolids need to assess the nature of their biosolids, the operational requirements and limitations of their land application program, and the storage option most suitable for their operation to select the best combination of design and management practices for their specific situation. To assist in this effort, specific design and management practices for various types of storage options are provided in Chapter 5.

References

CAST. 1996. Integrated Animal Waste Management. Council for Agricultural Science and Technology, Task Force Report No. 128, Ames, IA.

Chaney, R.L. and J.A. Ryan. 1993. Heavy Metals and Toxic organic Pollutants in MSW-Composts: Research Results on Phytoavailability, Bioavailability, Fate, etc., pp. 451-506. *In* Hoitink, H.A.J. and H.M. Keener (eds.), Science and Engineering of Composting. Renaissance Publications, Worthington, Ohio. 728 p.

Gerba, C. P. 1983. Pathogens. *In* A.L. Page, T.L. Gleason, III, J.S., Jr., I.K. Iskandar, and L.E Sommers (eds.) Proceedings: Workshop on Utilization of Municipal Wastewater and Sludge on Land. Univ. of Calif., Riverside, CA.

Hue, N.V. 1995. Sewage Sludge I: Amendments and Environmental Quality, pp. 199-247. *In* J.E. Rechcigl (ed.), Soil Amendments and Environmental Quality. Lewis Publishers, Boca Raton, FL.

Kloepper-Sarns, P., F. Torfs, T. Feijtel, and J. Gooch. 1996. Effects Assessments for Surfactants in Sludge-amended Soils: A Literature Review and Perspectives for Terrestrial Risk Assessment. The Science of the Total Environment 185:171-185.

National Research Council. 1996. Use of Reclaimed Water and Sludge in Food Crop Production. National Academy Press. Washington, D C. 178 pp.

Sharpley, M.A., J.J. Meisinger, A. Breeuwsma, J.T. Simms, T.C. Daniel, and J. S. Schepers. 1998. Impacts of Animal Manure Management on Ground and Surface Water Quality. *In* J.L. Hatfield and B.A. Stewart (eds.). Animal Waste Utilization: Effective Use of Manure as a Soil Resource. Ann Arbor Press, Chelsea, MI. 320 pp.

State of Maryland. 1994. 1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control. MD Dept. Environ. Water Management Admin., Soil Conservation Service and MD State Soil Conservation Committee. Baltimore. MD.